DILLON

Caisson Construction
for Chicago Buildings

Civil Engineering

B.S.

1906

CAISSON CONSTRUCTION

FOR

CHICAGO BUILDINGS

BY

FRED PAUL DILLON

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE 1906

U N I V E R S I T Y   O F   I L L I N O I S

May 30, 1906

This is to certify that the thesis prepared under the immediate direction of Assistant Professor F. G. Frink by

FRED PAUL DILLON

entitled CAISSON CONSTRUCTION FOR CHICAGO BUILDINGS

is approved by me as fulfilling this part of the requirements for the Degree of Bachelor of Science in Civil Engineering.

Ira O. Baker

Head of Department of Civil Engineering

TABLE OF CONTENTS.

ILLUSTRATIONS.

INTRODUCTION

Purpose of Thesis

The object of this thesis is to describe the methods of constructing concrete caissons for the foundation of large buildings in Chicago. The treatment of the subject will be confined to the writer's study of this kind of work during the summer of 1905, with special reference to the foundations of the Union League Club Annex, the Mercantile, and Mandel Buildings. Before entering into a discussion of these particular works, a review of the causes which developed this latest type of foundation construction seems necessary.

Part I

The Development of Foundation Building in Chicago.

Art. 1 Foundations for Early Buildings

The development of foundation construction in Chicago is a matter of rather exceptional engineering interest, particularly in view of the different methods employed to meet unusual conditions. The city is situated over a great clay bed, the upper part of which has hardened for a thickness of nine or ten feet. Below this and extending about ninety feet down to rock (but of varying depth) is clay of different degrees of softness, with streaks of quicksand here and there. This bed of soft clay is full of water in the upper part, directly under the old hardened crust, but gets dryer and harder deeper down, and at the bottom there is much course gravel with many glacial boulders.

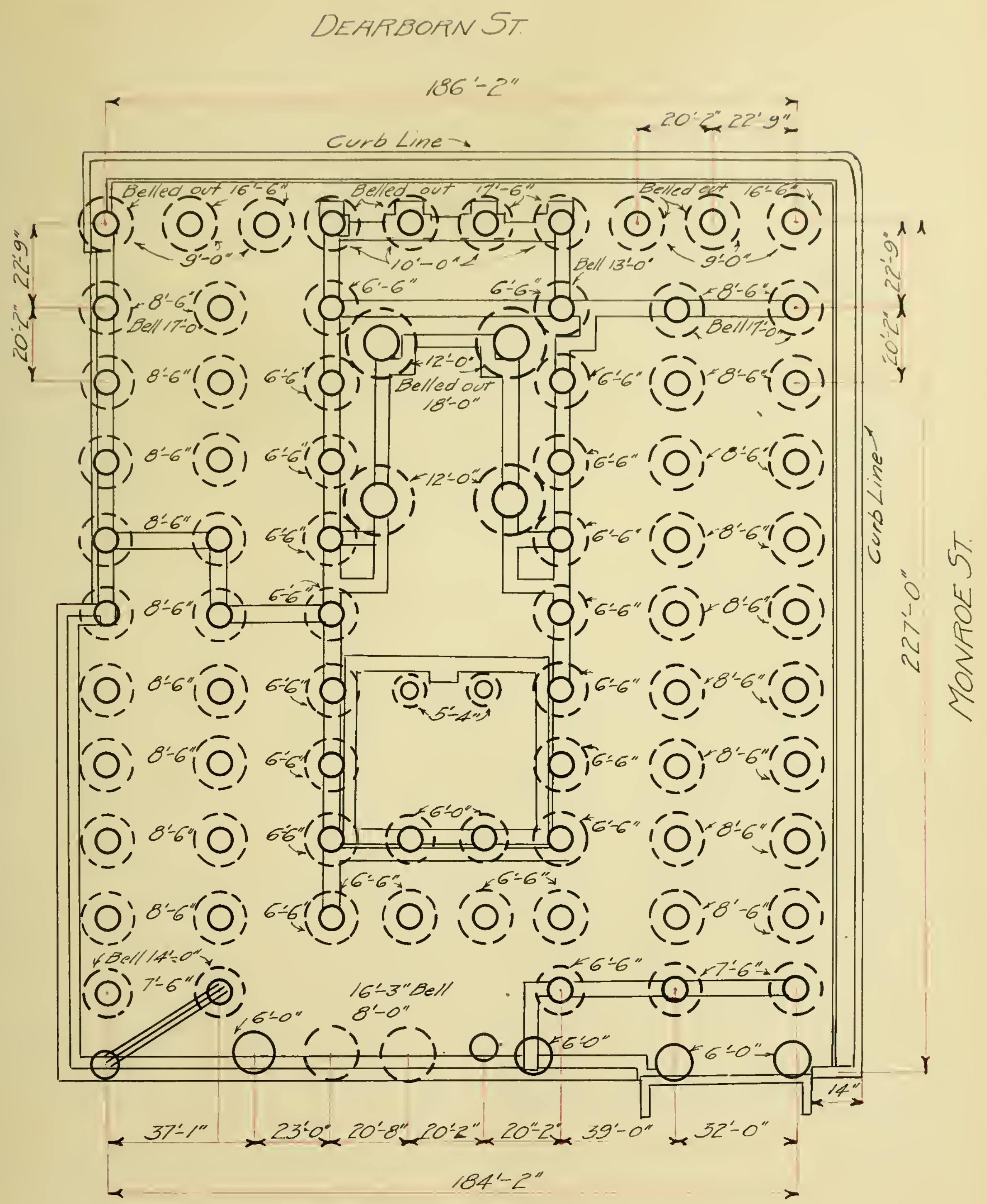
The foregoing conditions exist from the Chicago River south to 12TH Street, and from the lake shore west to the South Branch of the river. The elevation of the city was originally not more than four or five feet above average lake level, but after 1857 it was raised by filling in the streets and alleys, the buildings being then jacked up to the new elevation, which was about fourteen feet above datum (mean lake level of 1847). George Pullman, inventor and builder of the Pullman car, was one of the principal contractors for this work

The contractors and builders of those days had determined that a safe load for buildings on the hardened crust was from one and three quarters to two tons per square foot of foundation. The universal practice was to build piers of dimension stone masonry for foundations, the main or first floor of the building

being above street level and reached by steps. Cast iron shoes on the top of the piers supported the cast iron columns of the building. As buildings of eight and ten stories began to be designed, it was realized that the first floor must be level with the street, and that space between the street level and the level of the hardened crust must in some way be provided for the mechanical plant including boilers, etc.

Art. 2 – Spread Foundations.

It was not considered safe to excavate very deep into the hardened surface of the clay. Taking two feet for the construction of the first floor left only eleven feet to the bottom of the foundation. The result was that the basement was practically filled with stone pyramids and there was no room for the boilers, engines and dynamos, which latter began to be used about 1878. This question



PLAN OF FOUNDATION PIERS OF
FIRST NATIONAL BANK BUILDING, CHICAGO.
PLATE 8

came up when the Montauk Block was designed in 1878 by Burnham and Root. The ordinary stone pier construction was used for part of the foundation, but in order to make room for the boilers they devised a grillage of steel rails embedded in concrete, forming a shallow spread foundation. The Rookery, Rialto and Western Union Buildings were designed by the same firm, the steel rail grillage plan being developed in them into the I-beam grillage plan, which has since been used for so many tall office buildings everywhere in the United States. The Montauk Block was pulled down in 1903 to make room for the present First National Bank Building (PLATE 8 p. 4)

Art. 3 - Floating Foundations

The principle of the "floating foundation" was to carry the shallow spread foundations on the thin, hard, stratum covering the deep bed of soft clay.

underlying the city, keeping the load per square foot at a safe limit and avoiding all disturbance and penetration of the clay crust. It consisted in building a concrete steel grillage or platform for each column, this footing having rows of I-beams embedded in concrete. This shallow footing and steel columns replaced the heavy concrete and stone footings and piers which had previously been used, and it not only reduced the load on the foundation, but gave ample basement area, which was a matter of growing importance. The area of each footing was determined by the load which it was considered safe to impose upon the soil.

Art. 4. - Deep Foundations

While the floating foundation was used almost exclusively for several years, at the present time the deep foundation system is being used

for two principal reasons:-

First: The increased value of building ground which leads to a demand for sub-basement space in which the power plant and other appurtenances may be placed, leaving the basement free for business purposes

Second: The desire for greater stability. While the floating foundation was sufficient to support buildings of eight or ten stories, yet with the heavier loads of taller buildings the crust itself would deflect. The load per square foot of foundation would be no greater, due to the enlarged area of the footing, but the total load concentrated on a lot for a sixteen-story building being double that of an eight-story building for the same area, it was found that the architect had to deal with not only one and three quarter tons per square foot of foundation but also a double

aggregate load on the crust beneath the building, the area of the crust under the load remaining the same.

The opinion is held by some architects that the construction of deep foundations as well as the construction of water tunnels, telephone tunnels etc, has rendered the floating type of foundation undesirable for large buildings in the future owing to the disturbance of the clay. This doughy, plastic clay, when any cavity is formed in it, will gradually close it up, the movement of the mass extending for considerable distance

Thus in sinking shafts or driving tunnels, if any space is left outside the lagging, the clay body will move until this has been filled in. Shafts left unlined in the soft clay will gradually close and in one case where it was attempted to carry on pile driving at the same time as the shaft sinking, the upper

part of the shafts began to close up. After the construction of the Tribune Building, with deep concrete pier foundations in 1903, the Hartford Building on the opposite side of the street was actually one quarter of an inch lower than before.

The disturbance of the clay has lead to some irregular settlement of older buildings having the spread or surface foundations. In one particular case deep foundations have been sunk to stop the settlement of the original spread foundations, which was becoming serious.

Art. 5 Pile Foundations.

Pile foundations have been used in a great number of cases sometimes relying upon the skin friction of the piling to a great extent, but generally having the piles driven to hardpan or rock. The site of the Chicago Stock Exchange Building built in 1893. was found to consist of a fifty five-foot

stratum of clay which contained fifty five pounds of water per cubic foot and seemed likely to settle indefinitely under load. Gen. Wm Sooy Smith, the consulting engineer for the work, concluded to go down to hard clay using piles mainly. Near the adjacent building where pile driving might be dangerous to existing structures, five-foot shafts were sunk to a depth of fifty five feet being lined with oak poling boards four feet long and braced inside by heavy iron hoops (PLATE I p.25) These shafts were filled with rubble and concrete forming foundation piers. For detailed description of this construction see page 23.

Pile foundations were adopted in 1893 for the Chicago Public Library The piles were fifty feet long and were put down twenty seven feet in soft clay and twenty three feet in compact clay. It was required

that they should carry thirty tons per pile and test made under fifty-ton loads showed not settlement after eleven days. For the new post office it was intended at first to have concrete piers. Steel cylinders twelve to fifteen feet in diameter were to be sunk to hardpan at a depth of seventy two feet and filled with concrete. Gen. Wm Sooy Smith advised the use of piles on account of the saving in cost. Hardpan was reached by the use of fifty-foot piles driven in the bottom of excavation twenty eight feet deep.

Art. 6 - Caisson Foundations

As far back as 1892. Gen Wm Sooy Smith advocated carrying foundations to rock at depths of sixty to one hundred feet in places, or to the hardpan overlying it. He proposed sinking wells or shafts to a sufficient depth below datum and then driving piles to the solid formation. It is this well system of foundations which

is now being used almost exclusively but without any piling, the wells being sunk to the stable material, either rock or hard pan and then belled out to form enlarged footings.

In all cases the shafts are sunk as open wells. A great variety of material is met with and there is always uncertainty as to what materials and difficulties will be encountered at any particular site. Test borings do not give results that prove the facility of excavation and only the excavation itself discloses the conditions. In no case has the pneumatic process been employed but in one case steel cylinders had to be substituted for the timbering in order to enable the wells to be sunk through a pocket of quicksand.

The use of steel cylinders was required for the wells under the Chicago Edison Co's building at 84 Market Street to carry the shafts.

through quicksand. The architects were, Shipley, Rutan and Coolidge and Wells Bros. Co. General Contractors of Chicago did the work. The writer is indebted to the above named contracting firm for this information relating to the foundation work. The dimensions of the site were about 75 by 90 feet and quicksand covered the entire area, being ten to twelve feet thick with its surface 100 feet below street grade. No clay nor hardpan was found below the quicksand but there was a layer of boulders varying from the size of cobble stones to stones four and five feet in diameter overlying the rock. Twenty four wells in all were sunk, eighteen being six feet six inches and six being eight feet six inches in diameter. The ordinary method of sinking wells, which will subsequently be described, was followed until the quicksand was

reached. A steel cylinder was then put down made in three sections with vertical joints fitted with angle iron flanges for the connecting bolts. The excavation was at once started and as the sand was removed the cylinders settled by their own weight until they rested on the boulders overlying the rock. The boulders then had to be drilled and split. It was found hard to settle the cylinders after they had stood for several days and it was necessary to use jacks to force them down so that the bed rock could be cleaned and the concrete filling put in.

One advantage in the use of the system of wells is that after their construction a sub-basement can be excavated without affecting the foundation. This was done under the store which is now owned by Carson, Pirie, Scott and Co. While

this does not affect the foundation of the building itself it may affect adjacent buildings unless great care is taken to hold back the clay, the plastic, flowing character of which has already been mentioned.

This trouble was encountered at the Tribune Building where the central part of the site was excavated first resulting in a movement of clay which caused some trouble before it could be controlled. In preparing for the Republic Building at State and Adams Streets, the contractor, Wells Bros. and Co. excavated a trench around the site and built a curb wall of concrete reinforced with heavy steel I-beams, strong enough to resist the outside pressure.

Recent examples of buildings with deep foundations are as follows:- Tribune Building and Stong Building, seventeen stories each; First National Bank Building;

Merchants Loan and Trust; Railway Exchange; Marshall Fields Store; Mandel Building; Union League Club Annex, County Building; etc. In fact the matter of foundations for buildings in Chicago has settled down to one of two types; - pile foundations or caisson foundations both of which reach to hardpan or rock. The McNeill Building has caissons under the party walls and pile foundations for the interior piers. The same plan was adopted by Frost and Granger for the Hibbard, Spencer and Bartlett Building and the La Salle St. Railway Station. Under the First National Bank are caissons six to ten feet in diameter going down to rock which is found at a depth of 102 feet below street grade. At the Marshall Field Store and the Railway exchange the piers extend to a depth of about 90 feet where they rest on hard pan

overlying rock. In these cases the piers were enlarged at the bottom so as to reduce the pressure to five tons per square foot of surface covered. At the Tribune Building the wells struck hard material at various depths. At the County Building 120 wells are being sunk at the time of writing mostly eight and ten feet in diameter.

It is worth noting that in several cases the caisson foundations for new buildings have been put down under old buildings, without interfering with the use of the latter except that the basement is vacated for the use of the contractor. In this way the period during which the site is unproductive of rent is reduced to a minimum. When the caissons are finished it is a comparatively quick and easy matter to pull

down the old structure and erect a new one. A specific instance of this is the case of the reconstruction of one of the Marshall Field Stores at State and Washington Streets. At the time of writing wells are being excavated under the building which is to be wrecked but which is still open for business as the work goes on underneath.

PART II

CAISSON FOUNDATIONS AS CONSTRUCTED FOR THE UNION LEAGUE ANNEX, MERCANTILE AND MANDEL BUILDINGS.

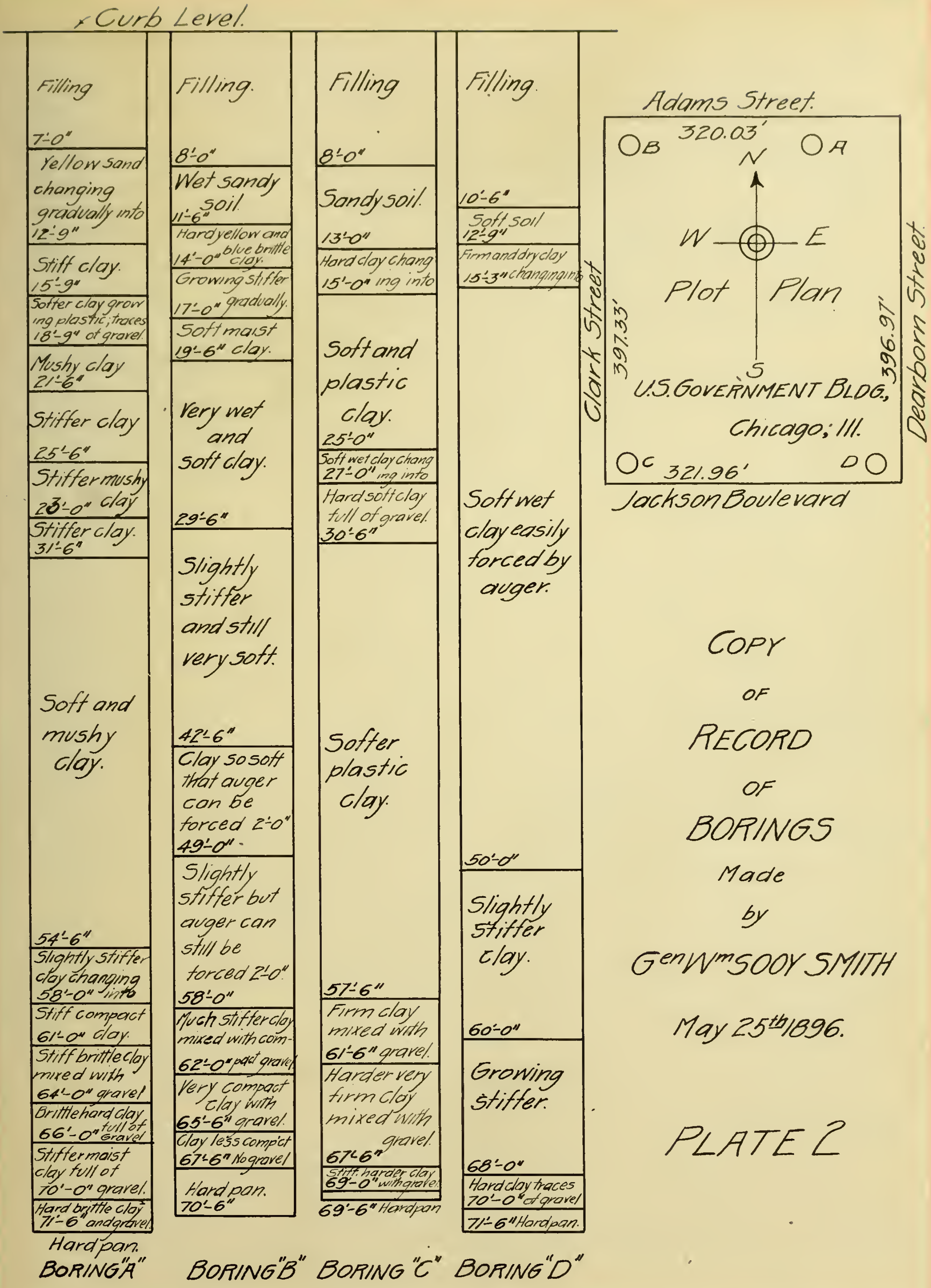
Art. 1 – Location of Buildings.

Referring to page 1 it is seen that the Union League Annex, Mercantile and Mandel Buildings are taken as examples from the construction of which the writer has obtained the information herein set forth in regard to caisson construction. The first named building is just south of the Union League Club on the corner of Jackson Boulevard and Custom House Place. It is a fire proof structure 48 x 97 feet, seven stories high in addition to a basement and sub-basement. The various floors are used as engine room; kitchen; bath, bed, and toilet rooms; check and locker rooms; lounging rooms; barber, shop; etc. It was never intended that the

floors should sustain unusually heavy loads.

The Mercantile Building is located at 138 State Street and at the time of writing is occupied by Lloyd's Department Store. It embodies the latest type of fire proof construction — even more than the Union League Club Annex. It is 69 x 117 feet, seven stories high, designed to carry eleven additional stories in the future. The floors are designed to carry heavy loads such as crowds of people, great piles of merchandise and various other live loads. What is said concerning the Mercantile Building is also true of Mandels new addition to their department store at 111 Wabash Ave. This addition is 71 x 172 feet, twelve stories high with four additional floors below street level. The entire basement is surrounded by a retaining wall which reaches forty five feet below street grade.

These three buildings are founded upon concrete caissons. A concrete caisson as referred to in this paper is nothing more than a cylindrical, circular well filled with concrete, the sides of the well being kept from caving in during excavation by a wooden lining. The depth of the excavation or well for caissons varies with the class of building. In either case caissons are either founded upon hardpan or bed rock. The object of going so deep for a foundation is to obviate the possibility of unequal settlement that is likely to occur if the foundation is laid on the top of the peculiarly unstable Chicago soil. The caissons under both the Mercantile and Mandel Buildings are bed rock caissons, going down to depths of 87 to 105 feet. The caissons for the Union League Annex are on hard pan at depths of 65 to 75 feet. The depths at which hard-pan and bed rock may be reached varies in different parts of the city



COPY OF RECORD OF BORINGS Made by Gen Wm SOOY SMITH May 25th 1896.

PLATE 2

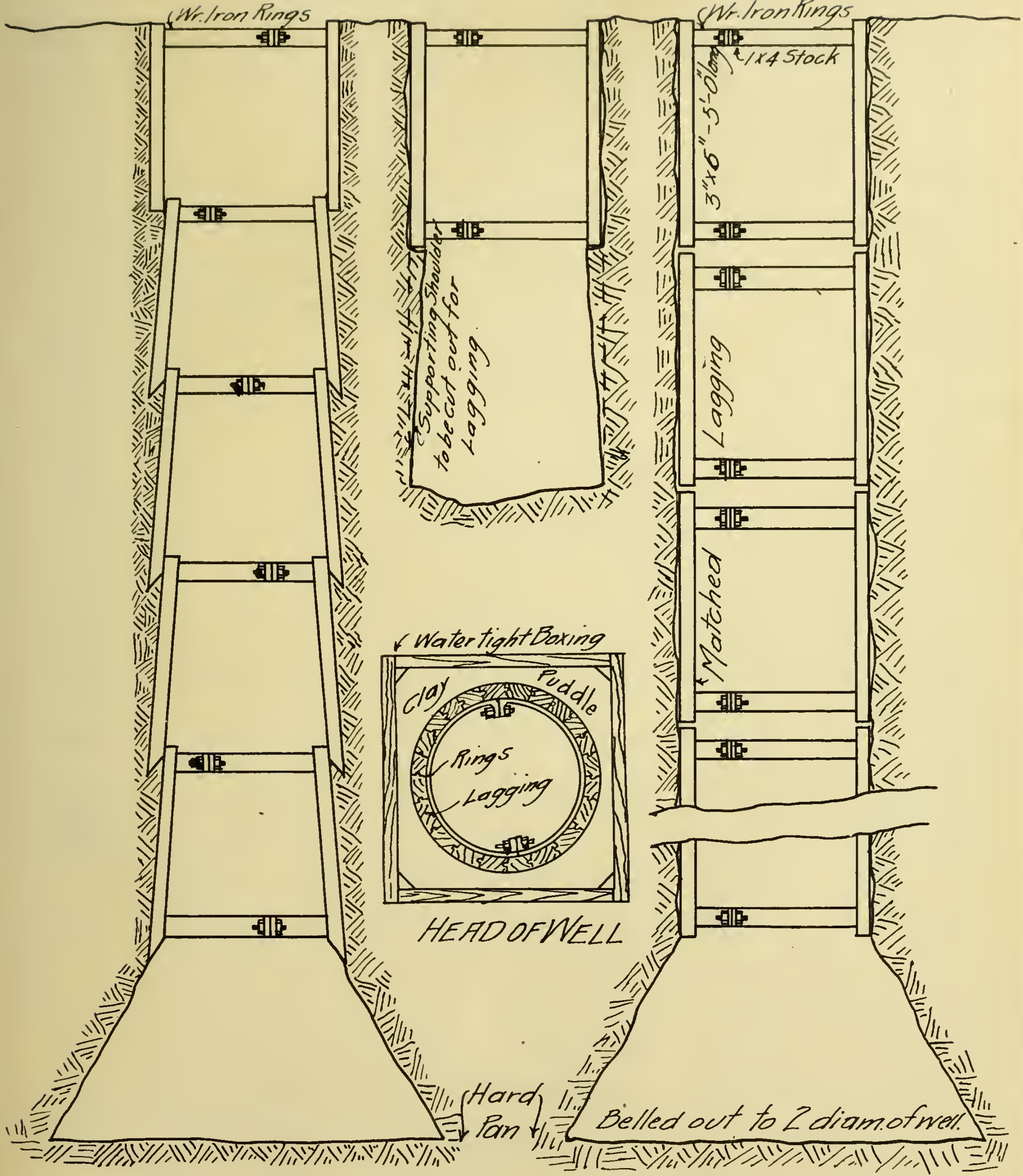
Plate I page 25 shows something of the nature of the soil and the variations in the depths of the different strata as ascertained by borings in the site of the U. S. Post Office Building.

Art. 2 – Development of Wm Sooy Smith's Plan for Caisson Construction into Practice.

On account of the nature of the soil underlying the city of Chicago, the problem of foundation building has been of vital importance. For this reason Chicago has lead the world in the art of putting in foundations. The last and as yet the most satisfactory step in this line of construction has been the adoption of the concrete caisson. This idea was first worked out by Gen. Wm Sooy Smith in 1892, although the plan that he first used has since been perfected somewhat. This type of foundation was first used under the west columns of the Stock Exchange Building. This wall was loaded very heavily and a very small

settlement would cause thousands of dollars damage to the heavy presses located near it. Four five-foot and four six and one half-foot wells, at twenty foot centers were sunk. The method of procedure was as follows. The excavation for the pier was carried down four feet under the wall. A steel ring 1"x4" stock with flanged ends was placed in the pit in two sections. Sheeting or lagging as it is termed was placed vertically around this ring. Another ring was then placed at the top of the lagging thus completing that course. Clay was puddled around the outside and every possible means was used to get the earth packed firmly around the lagging to prevent the surrounding material from caving in. Another ring, six inches smaller in diameter than the one above was placed in the bottom of the hole and the lagging set about it being driven down as far as possible.

PLATE I



METHOD FIRST USED BY Wm. SOOY SMITH — LATER DEVELOPMENT

METHOD OF BRACING WELLS FOR CONCRETE CAISSONS.

The excavation was carried down to within eight inches of the bottom of the logging. The logging was again driven and the material within removed. By this means the logging was kept ahead of the excavation and tight against the surrounding earth. When hardpan was reached, the well was belled out to increase the bearing area. The well was then filled with layers of rubble stone and concrete, the rings being taken out as the well was filled. See PLATE I page 25 for method first used by Gen. Wm. Sooy Smith.

There is essentially no difference between the method employed by Gen. Wm. Sooy Smith and the one used in caissons more recently constructed. Under ordinary conditions the sides of the well will retain themselves for five feet, the length of one course of logging. Owing to this fact the logging may be put in vertically,

the course above being sustained by a shoulder of clay until the excavation for the next course is completed. The supporting shoulder is cut out and the logging put in place. See PLATE 1 for method more recently used. With the increasing weight of buildings the size and depths of the wells have increased over the first ones constructed and concrete is used exclusively for filling. F.

Art. 3 – Method of Disposing of Material

The conditions which govern the removal of excavated material from wells for caissons are different for almost every contract. Formerly all soil was carted away from the site which necessitated either a runway into the premises or some hoisting and loading space. The objections to this method of removing material in a crowded city like Chicago are manifold. In order to have the work go on smoothly there must be

plenty of wagons at hand; yet a crowding of wagons waiting to be filled means a blockade in the street which if repeated calls for action from the city against the contractor. Pulling wagons up a steep incline, as is often done is very hard on the wagons and horses; besides the runway takes up valueable space Added to these objections is the nuissance of scattering dirt on the pavement, sidewalks, etc from the loosely constructed dump wagons.

The advent of the Illinois Tunnel Company, with its underground carriage system beneath almost all the principal streets of Chicago, does away with the old cartage method of removing material from new construction in the business district All the material excavated from the wells of the three buildings under discussion was removed through the "Tunnel".

The Illinois Tunnel Co. builds a spur from the street to the property line, the floor of the tunnel being about forty feet below street grade. At the end of the spur a riveted steel tube, four feet in diameter is sent up into the sub-basement of the building at a sharp inclination. Cars can be run under this tube and after they are filled they are hauled quickly away by a motor to the dumping ground which at present writing is on the lake front. This method of disposal is quick, convenient and does not interfer with surface traffic. It is altogether scientific.

What was formerly a very difficult part of the problem to be considered - namely the disposal of material is solved in a simple manner. The next part of the work is the caisson itself. The sizes and location of the caissons are questions for the architect to be determined by

(a) the class of building to be sustained; (b) the character of the structures adjacent the one contemplated, as to whether these buildings are on caissons or not and (c) the disposition of the owners of adjacent buildings toward party wall caissons. The unit weight allowed upon caissons is generally twenty five tons per square foot. Great care has been taken in sinking caissons near a building with floating foundations on account of destroying the equilibrium of settlement of the mushy soil. It is nearly always the aim of the owner to get the consent of the owners of adjacent buildings to caissons under the party wall if the buildings are so constructed. If there is no party wall then the caisson must all be built within property lines which necessitates what is called cantilever construction for the columns of the side walls. The Union League Annex has the

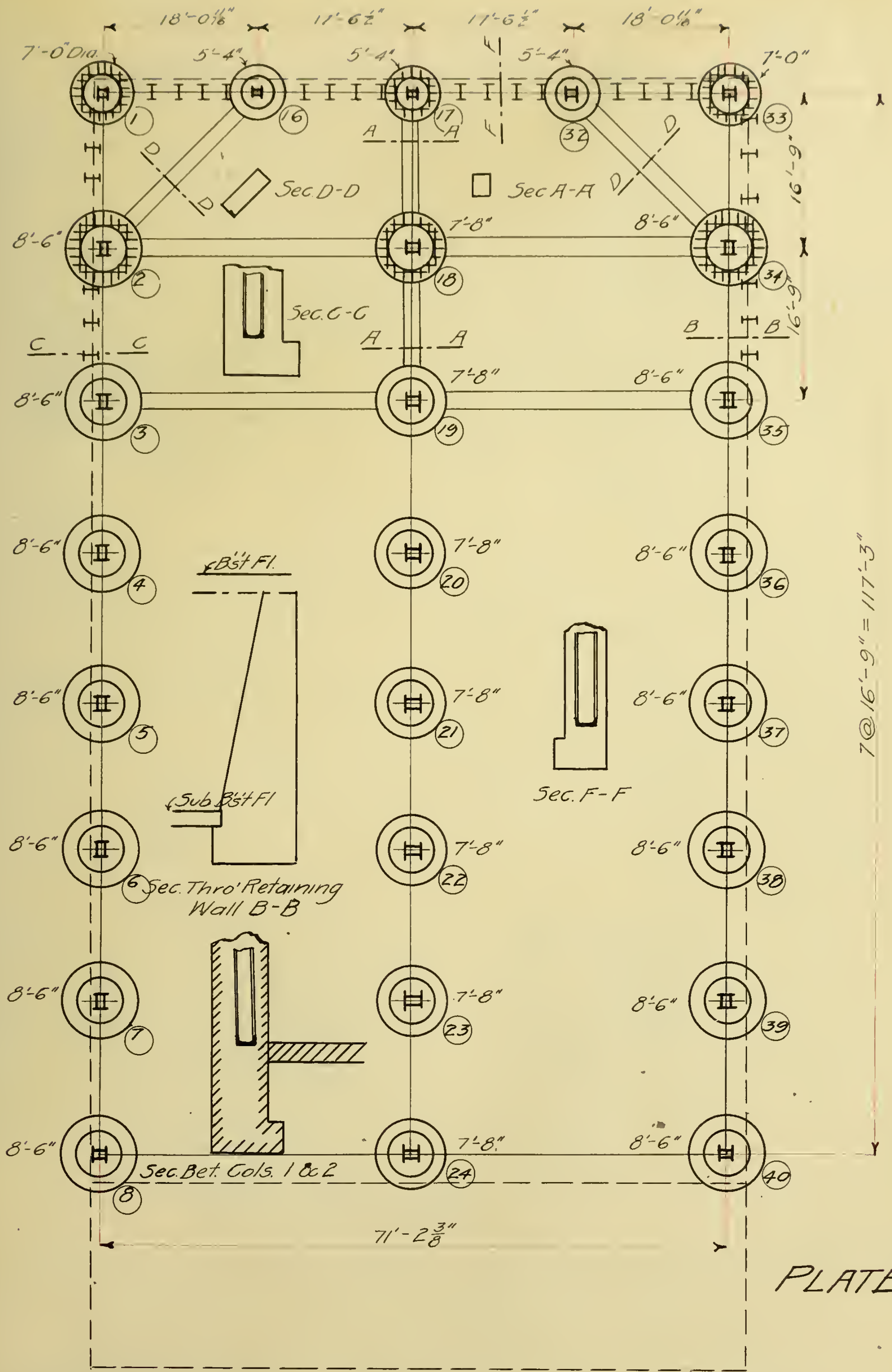
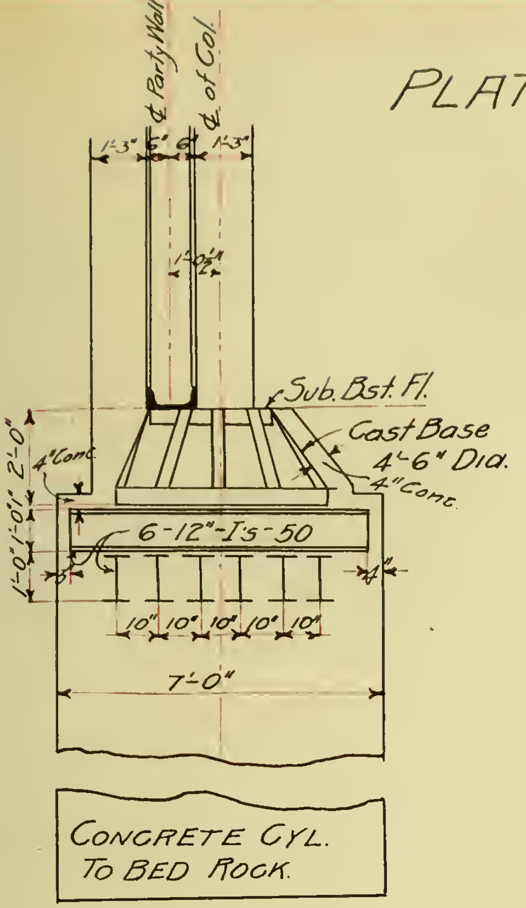


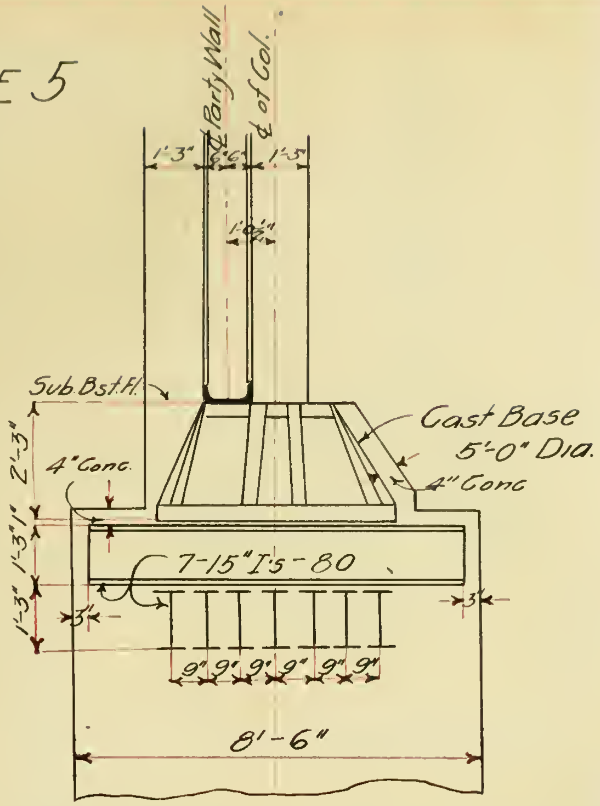
PLATE 3.

FOUNDATION PLAN OF MERCANTILE BLDG., 138 STATE ST., CHICAGO

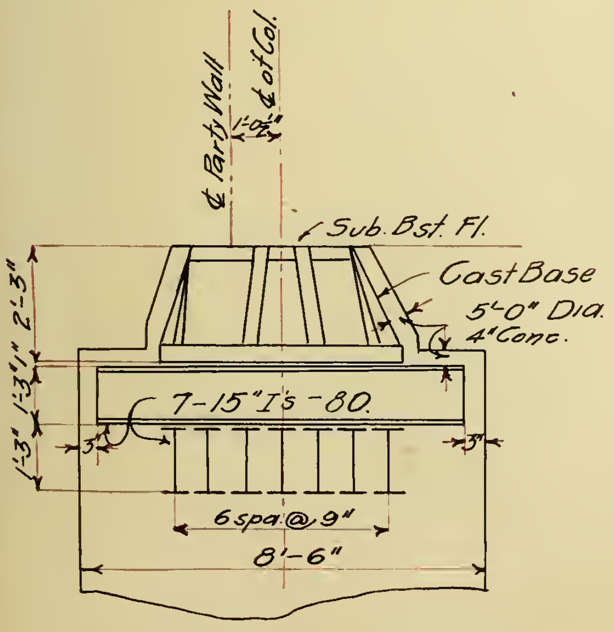
PLATE 5

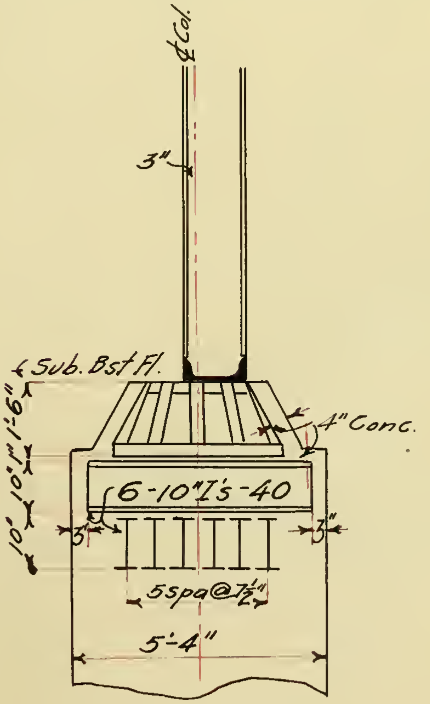


FOOTING FOR COL. 1.



FOOTINGS FOR COLS. 2 & 3





FOOTING FOR COL. 4 TO 8

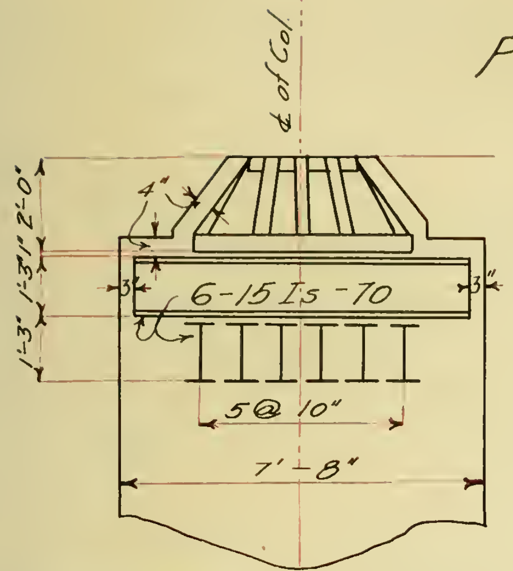
FOOTING FOR COLS. 16, 17, 32.

DETAILS OF CAISSON FOOTINGS

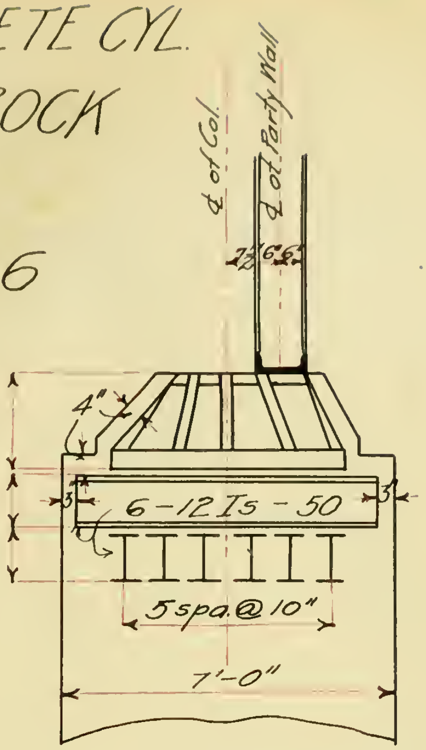
MERCANTILE BLDG., 138 STATE ST., CHICAGO, ILL.

ALL CONCRETE CYL. TO BED ROCK

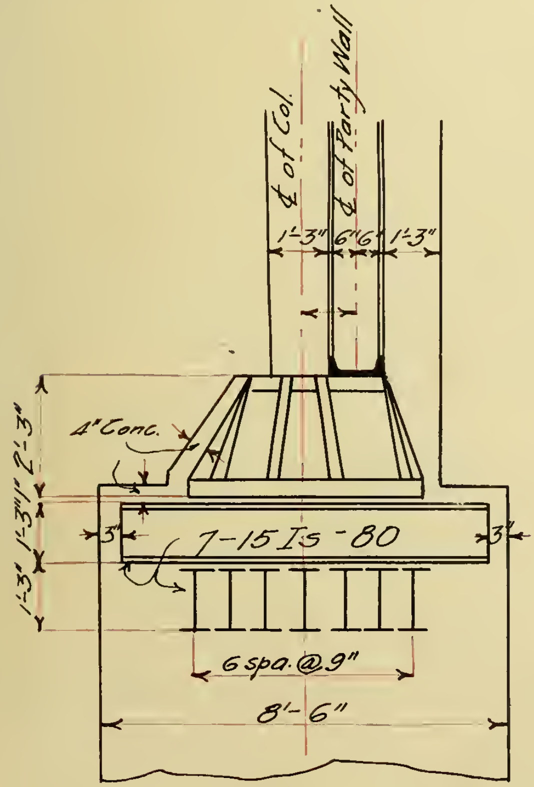
PLATE 6



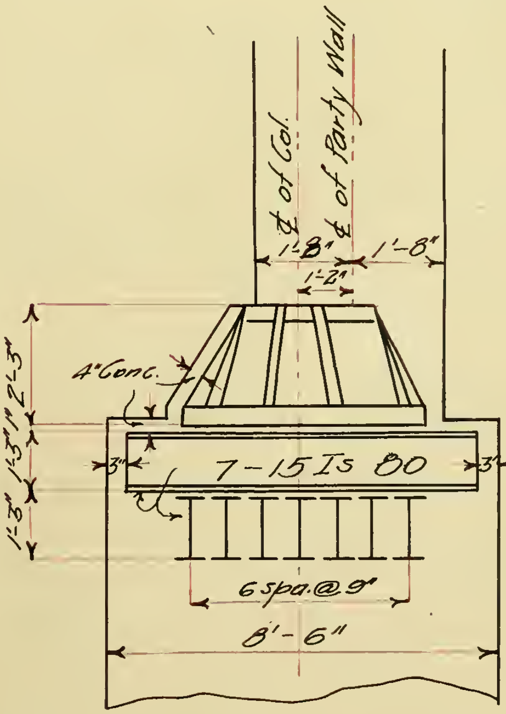
FOOTING FOR COLS 18 TO 24



FOOTING FOR COL. 33



FOOTING FOR COLS 34 & 35



FOOTING FOR COLS. 36 TO 40

MERCANTILE BLDG., 138 STATE ST., CHICAGO, ILL.

cantilever girders resting of the caissons The Mercantile and Mandel Buildings have their columns supported directly on shoes embedded in the concrete of the caissons

General Scheme — The basement should be cleared of all materials, such as former foundations, columns etc. Then the adjacent walls are shored up wherever the present columns, walls or fastenings interfere with the sinking of caissons. This shoring should be done by an experienced house raiser. The shores should be shifted as it is required to properly and expeditiously carry forward the work.

A cofferdam is then constructed around the head of each caisson, made of a water-tight boxing sunk into the blue clay and thoroughly puddled with clay around the outside to prevent all surface water from penetrating the wells. A center stake plumbed

from the top of the well is used continuously for carrying down the work and every caution should be taken to make the excavation the net diameter of the outside of the lagging, and thus avoid all open space between the back of the lagging and the face of the excavation

The lagging is three-inch matched staving in five-foot lengths, held in place with heavy wrought iron sectional rings. These rings are put in place in sufficient numbers to prevent all bulging or movement of the lagging. Generally the lagging is left in place as the caisson is filled with concrete but the rings may be so set that when the bottom ring is removed the concrete will retain the bottom of the lagging

All work of excavation and constructing of caissons is generally done with three shifts of men, twenty

four hours of every day continuously. Sundays and holidays included. Union rules interfered with this scheme somewhat in the summer of 1905. The prosperous times in Chicago and the building boom then made the price of labor high and put the labor unions on a strong basis. Nine or ten large buildings in the business district were erected with caisson foundations. Following is the scale of wages for work connected with caisson sinking:-

Kind of Work	Cents per hour
Well Diggers (one to four in a well)	45
Windlass and Signal men	40
Helpers, "muckers", wheelers and ordinary labor	30
Hoisting Engineers	60
Men at Engine Drum	45

Time and one half is allowed after eight hours; double time after four hours on Saturday; and double

time on Sunday.

Only experienced picked men are employed for digging. These are generally great strong fellows of Hibernian stock for only a few can stand this kind of work. A bonus is often offered them for completing the depth within a certain time. For the most part the material handled is a stiff, slimy, blue clay which can best be taken out in chunks cut out with the shovel. This clay is heavy and hard to handle. Moreover the footing on the clay is insecure which renders the handling more difficult. Often the small amount of room and the damp misty, muggy air renders the place unfit for ordinary men to work in. No effort is ever made to ventilate the wells unless a small office fan is dropped down to the bottom by the cord.

Occassionally a dry strata

of clay mixed with gravel is encountered. A fairly representative condition of the soil has already been referred to, for which see PLATE 2.

As to the effect of this kind of work upon the health of them men it is very hard to determine. Nearly all of them are such heavy drinkers that their physical break-down might well be attributed to this cause. It is a fact however that the well diggers soon lose their efficiency at that kind of work and are replaced by younger fellows who are anxious to secure the good wages.

The sizes of the wells vary according to several factors:— depth, height of building and the proportion of the load which each is expected to sustain. The diameters of these range from four to fourteen feet. One of the latter size is in the foundation of Marshall Field's Retail

Store on Wabash Avenue. The caisson under the Union League Annex are five feet four and four feet nine inches in diameter, the larger ones supporting the side walls of the building. These only extend to hardpan. The caissons under the Mercantile Building are seven feet eight and eight feet six inches in diameter and under the Mandel Building are four feet three to eight feet in diameter.

Art. 4 - Method of Hoisting Excavated Material from Wells.

Electricity, steam and hand power have been employed to elevate the buckets containing excavated material from the wells. The demands on each different contract determine the use of one or more of the above methods. In general hand windlasses are used where the wells are sunk under a shored party wall and in other places inaccessible to engines or motors. For buildings which are having the foundations

replaced with the anticipation of using the site for a new structure it is very often found economical to use electric motor hoists. This is the case in the basement of the Marshall Field Store at Washington and State Streets. The building will be subsequently torn down and replaced with a new structure on caisson foundations. The foundations for the new building are at present writing being put in as business is transacted above. It was found that the building was supplied with power sufficient to put in motors for hoisting. In similar cases the electric motor seems to be the hoist used.

On new structures where smoke and noise is not objectionable steam hoisting engines are generally employed to reach as many wells as possible. One engine can conveniently perform service for three or four wells at a time. Where the ground is cleared

to the foundations the method previously described of a continuous cable operating hoisting drums over each well in a circuit is the best method to employ.

In Chicago (1905) hoisting engineers were paid sixty cents per hour. When the electric hoist was used the price paid was one dollar and thirty five cents per hour which includes the use of the motor and the engineer.

There are proportionally more diggers injured in wells than other workmen in any other part of building construction. There seems to be lacking some precautions by which this might be averted. Some device might easily be conceived whereby men at work in the wells would be shielded from a dropping bucket. Some sort of a safety grating or shield might be employed in the shaft to protect the men.

The weight of a loaded bucket approaches five hundred pounds

The buckets are long cylinders, this shape being better for steady lifting or lowering. The bail has a loop in it at the center for the rope and it is near this loop that the breaking of the rope is most liable to occur. The signal man at the top of the well guides the bucket as it goes down or comes up and directs the engineer when to stop it when near the top or bottom. The friction spindle on the hoisting engine is used to raise and lower the buckets.

Where the work is nicely arranged as was the County Building the matter of disposing of excavated material was an easy one. There the bucket were dumped into chutes. Under these chutes a patent dump car was run on tracks which lead to an opening to the Illinois Tunnel. Beneath this opening were placed the cars which were filled and transported to the lake front where new land is being created.

Another danger attending the sinking of wells is the improper protection afforded the workmen from falling into the well when it is standing idle waiting for the concrete filling. The mouth of the well is usually boarded over but in addition it should be fenced in with a rough sort of fence. Two accidents to men falling into wells and five where buckets fell in some way or other were recorded on two buildings in one month. Of course a more careful superintendence would help to obviate this matter.

In Chicago there is a certain distinct class of laborers who follow the business of foundation building and who might in a way be called skilled laborers. There is no small amount of skill required in keeping the bore of a well true which is so essential to prevent the movement of clay and it is a matter of pride among

the diggers to do this. If an inexperienced engineer should have charge of this kind of work it would be advisable for him to look into this matter a little and try to secure laborers experienced in this particular class of work.

Art. 5 - Cost of Excavation

The cost of sinking wells varies between such wide limits that it is hard to state what would be an average cost for this class of work. For example in the basement of Marshall Field's Store, on the northeast corner of State and Washington Streets, wells were sunk some of which penetrated a stratum of cemented gravel. The progress through this material was as little as one foot per day, making the cost of labor run up very high. The location of the well with respect to overhead walls, framing, etc. and the ease with which hoisting apparatus may be rigged up also determine

the cost of excavation. Where the ground is cleared to the soil very often a scheme can be used which reduces the cost of hoisting to a minimum. This scheme is used at the present writing for the excavation of the wells in the County Building and has be referred to before. Briefly it is as follows. A hoisting engine is conveniently situated near the wells. Over each well in a circuit is built a small frame which supports a friction drum. A continuous cable propelled by the hoisting engine passes around the circuit of wells and rotates the drums over each opening. An operator at the drum can raise the bucket from the well by simply taking a few turns of the bucket-rope around the revolving drum and tightening the turns.

In a majority of instances wells are in cramped quarters where only two or three at a time

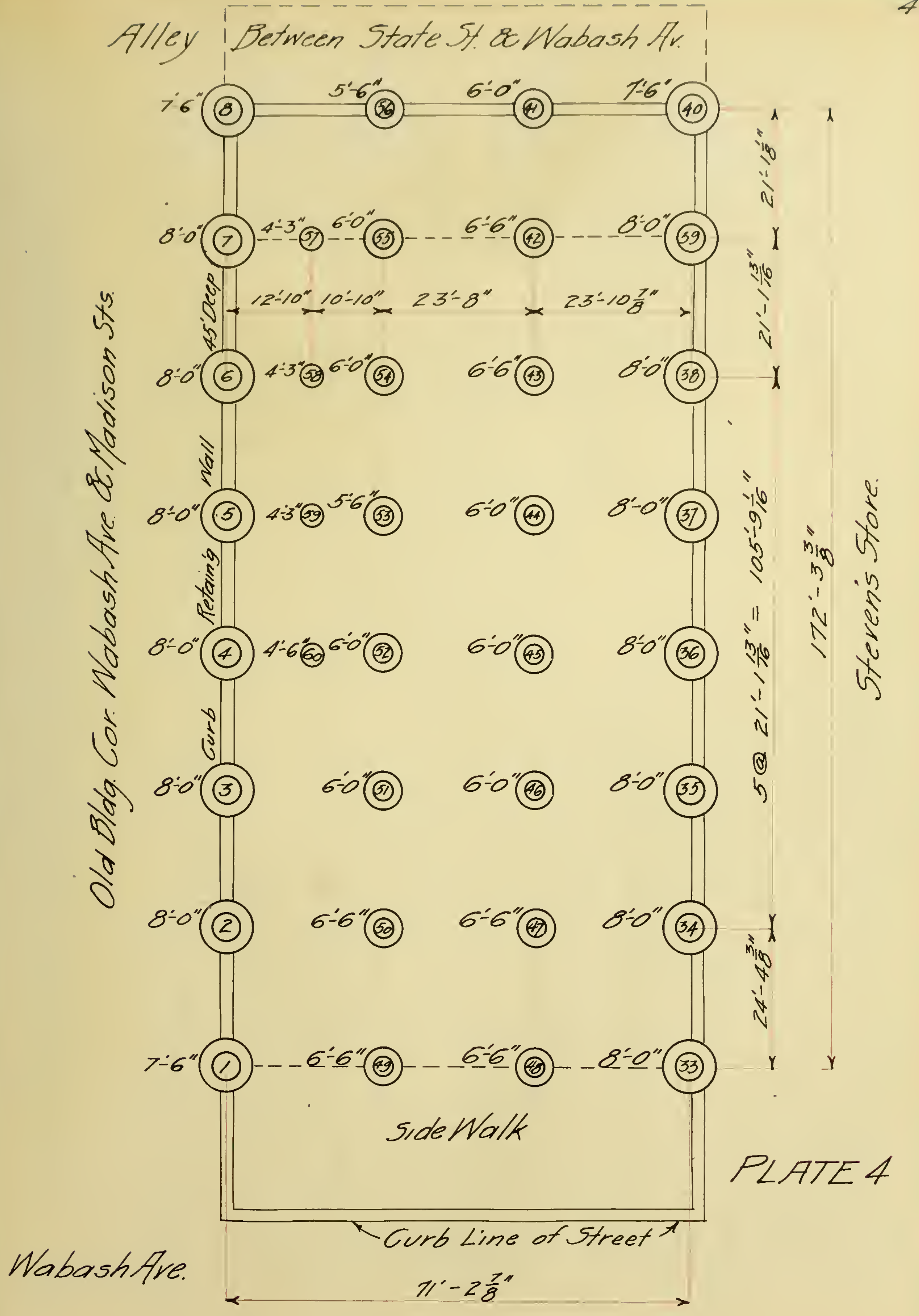


PLATE 4

MANDEL BLDG. DEPT. STORE, 111 Wabash Ave., Chicago. Ill.

TABLE SHOWING

TIME REQUIRED FOR EXCAVATING & CONCRETING WELLS

COST OF EXCAVATION

Well	Size of Well		Time for Excavation			Labor Cost & Wage Scale per Hour					Concreting		
No.	Diam.	Depth	Started 1905	Finished 1905	Total Hrs.	45¢ Diggers	40¢ Windlass	40¢ Signalmen	30¢ Labor	Total for Excavation	Started 1905	Finished 1905	Total Hrs.
33	7'-6"	97'	3/8-11:30 AM	3/15-12 M	$168\frac{1}{2}$	171.00	57.60	18.20	43.20	290.00	3/15-8:15 P.M.	3/16 1:30 P.M.	$17\frac{1}{2}$
34	8'-0"	96'	3/3-9:30 "	3/10-8:00 AM	$166\frac{1}{2}$	204.50	108.80	48.00	19.60	380.90	3/10-10 A.M.	3/11-11 A.M.	25
36	8'-0"	92'	3/3-1:00 P.M.	3/9-9:30 P.M.	$152\frac{1}{2}$	186.75	57.60	41.50	18.50	304.35	3/10-2 "	3/10-6 P.M.	16
40	7'-6"	99'	3/6-12 M	3/14-4 P.M.	196	194.40	68.80	60.20	51.60	375.00	3/14-4:30 P.M.	3/15-8 P.M.	$27\frac{1}{2}$
41	6'-0"	103'	3/4-1 P.M.	3/14-1 A.M.	232	144.00	112.00	22.00	43.20	321.20	3/14-11:30 "	3/15-3 "	$15\frac{1}{2}$
57	4'-3"	86'	3/5-12 P.M.	3/9-9:30 P.M.	$93\frac{1}{2}$	36.00	51.20	21.60	—	108.80	3/9-10 P.M.	3/10-5:30 A.M.	$7\frac{1}{2}$

In addition to above cost of excavation should be added Hoisting Engr's time superintendence, materials etc.

Following are cost of excavation of several other wells derived in the same way. All work was carried on continuously in 8-hour shifts:—

Well No. 35 -- 8'-0" - 89' -- $311.60
" " 37 -- 8'-0" - 96' ---- 366.00
" " 60 ---- 4'-6" - 84' ---- 195.30
" " 45 ---- 6'-0" - 87' ---- 277.60
" " 46 ---- 6'-0" - 91' ---- 263.50
" " 49 ---- 6'-6" - 89' ---- 215.60

MANDEL BLDG 111 Wabash Ave., Chicago, Ill. PLATE 7

are conveniently located for a hoisting engine. Under these conditions which are more nearly representative of the average, the wells in the Mandel Building were sunk. Following is PLATE 7 p.47 showing the cost of excavating a few wells sunk under fair conditions for that foundation.

Art. 6 - Concret Filling

The concrete filling for wells is generally composed of one part Portland cement, three parts clean, sharp, fine washed Torpedo sand, and five parts of broken stone of random size ranging from one half to one and one half inches. In the case of the Mercantile Building and the Union League Annex screenings were substituted for Torpedo sand. Any approved brand of Portland cement is used providing it fulfills the following requirements:— ninety five per cent must pass 100-mesh screen. Tensile strength must be above one hundred and seventy five pounds per

square inch for seven days set, one in air and six in water. All cement must be tested by an engineer approved by the architects of the building. It is seen that the above requirements admit of the use of almost any Portland cement now on the market.

A Smith concrete mixer was used on these buildings and appeared to have ample capacity to do the work. With the machine in good order and the materials conveniently placed the Smith mixer had a capacity of about seventy five cubic yards in a shift of eight hours.

The concrete was lowered into the wells in the Mandel Building through a telescopic sheet steel chute. At the lower end of this chute was a section made to swivel, with handles for swinging so that the concrete could be evenly spread. The size of the chute was calculated so that the interval of time occupied by the passage of the

concrete through the tube should not dangerously approach the limit of initial set of the concrete.

Two men were kept in the well during the filling to spread and tamp the concrete and remove the rings as before mentioned. However the tamping was often pitifully neglected unless a strict guard with shot guns could be maintained over the two men. This does not alter the fact that the specifications called for tamping of concrete in six-inch layers.

What has been said in regard to filling and tamping applies to the Mandel Building only. In the other two buildings under discussion the specifications were very lax about this matter. As a consequence the contractor adopted a much more simple means and one much to be condemned if not carefully done. The men simply wheeled their barrows

full of concrete to the edge of the well and with the aid of an assistant dumps them into the hole. The result of dropping concrete from great hights is very much condemned by prominent engineers. However it cannot be said that the concrete would not be sufficiently tamped if it fell some sixty or eighty feet. At the same time the under layers would have their initial set destroyed from the impact thus weakening the mass. Opposed to this fact is another, viz,- the caisson does not depend on its inherent strength for its usefulness. A column of sand surround as is the caisson might make an adequate footing for a time. Nevertheless it seems that if a simple device such as that used for filling the Mandel wells could be devised good judgement would be to do away with dropping the concrete from the top.

From the contractors, point of

view here is another presentation of the matter of dropping concrete into place. There are two methods employed in placing the concrete filling, either by lowering it through a telescopic steel chute as previously described or by simply dumping it in from the top, letting it fall the whole distance. Obviously the first method is a good one but slower than the second. But what are the objections to the second. In the opinion of several contractors who have had large experience with caissons the method of dropping concrete into place if properly done by competent laborers. Of course if a wheel barrow filled with concrete is brought to the opening of the well and spilled into the well the mixture falls separated. When it strikes the bottom a little mound is built up; the stone of the concrete rolling down the slope and the

mortar building up in the center. As each successive wheel barrow load is dumped from the same place this action continues so that the caisson is finally built up of mortar in the center and a ring a foot or so in thickness of uncemented stone around the outside.

On the other hand if the concrete from the wheel barrow is dumped as a mass and falls quite a distance to the bottom the impact of this mass does more toward compacting the concrete than any amount of conscientious tamping could possibly do. Laborers who know how this work aught to be done can dexterously place these individual loads as neatly around in spots as if they lowered them to place by hand. On this basis then the contractor claims that this method of filling

is the better. The pier builds up forming a homogeneous mass throughout and is thoroughly compacted. If the labor employed is not experienced in this work the method as described with the use of the sheet steel tube should be employed.

The upper fifteen inches of each caisson is composed of one part cement, two parts fine granite chips and in the top is embedded the grillage which supports the cast iron bases of the columns. See PLATE 5&6 page 32. This grillage consists of I-beams in two layers at right angles to each other which gives a bearing over the entire top of the caisson.

Art 7 – Tunnel Construction as Affecting the Foundation of Buildings in Chicago

The settlement of streets in Chicago and the effect of this movement of the ground in relation to building foundations has become a matter of serious consideration. A special commission

of engineers was appointed in 1905 to investigate the affect which the digging of the Illinois Tunnel had upon the settlement of several streets and buildings. The Tunnel Commission was composed of John McEwen, M. Am. Soc. C. E, E. C. Shanklin, M. Am. Soc. C. E., and L. E. Ritter. The first report of this commission presented the conclusions that no settlement had occurred where the main tunnel had been built under air pressure, but that there was convincing evidence that such settlements had occurred as a result of the building of connections, by-passes and new drifts without air pressure. The reasons for these conclusions are clear when the following report of Aug 24, 1905 is read:—

"In our report of Aug 14, 1905 we (the commission) stated that we could find no damage due to settlement of streets or buildings where the

work was confined to the main line tunnels. It was not until the greater portion of the tunnels were finished in the down-town district and the work of making connections to buildings was attempted that settlements were noticed. The main tunnel as constructed in each case, below the middle of the street, fell outside of the lines of pressure from the buildings on either side.

In the case of the by-passes it is appearant that the excavation would be in clay that was under pressure from the weight of these buildings as well as under pressure from the weight of the clay above."

Following are a few examples which lead the Commission to make the statement quoted above.

1. The settlement at the intersection of State Street and Jackson Boulevard; northeast corner of the Pullman Building; Adams Street in front of

the Republic Building and the south west corner of Marshall Field Wholesale Building. In the above report it is further conclusively shown that improper bracing or ignorance concerning the handling of such pressures while constructing the piers was the cause of all of the settlements. The facts which lead to these conclusions are discussed at too great length to be presented here.

The Illinois Tunnel Company has permits to connect with many buildings but to the writers knowledge it has completed only four connections in addition to the connections to its own buildings. The connection to the Heyworth Building is a curve of the tunnel into the deep basement of that building on the same level as the tunnel. The Heyworth Building stands on caisson foundations. Other connections are to the Majestic theatre on Monroe Street; Marshall

Field's Retail Store and the Mandel Building, all of which are on caisson foundations.

There is no reason why these connections should not be put in providing a scheme be devised to meet the conditions which are peculiar to each case. It is manifest that the least complicated cases will occur when the buildings to be connected stand on caisson foundations. Even then damage may be expected to adjacent buildings that stand upon spread foundations. Buildings resting upon pile foundations may be classed in most cases with buildings on caisson foundations.

The cases where old buildings have been erected upon spread foundations would probably present a great many difficulties and a plan would have to be care-

-fully studied out to meet each case. The most difficult and dangerous cases to handle are those of the tall, heavy buildings resting upon spread foundations.

Conclusions:-

From what has been said in regard to the development of foundation construction in Chicago; on account of the increasing weight and height of buildings, settlement and tunnel construction, there are at present only two classes of foundations which fulfill all the requirements which are being demanded. The pile foundation and concrete caisson foundations are both employed; the former on account of lower cost holds its place against the concrete caisson. The pile foundation referred to here is the one in which the piles are driven to hardpan. In the opinion of most engineers the pile foundation are much more in-

certain than caisson foundations and very often settle even in hardpan. The objection to driving piles in the city is often prohibitory to their use. There is absolutely no chance for a building to settle if it is built on caissons resting on bed rock and very little if any chance for settlement if the caissons rest on hardpan. As was previously stated, specifications now generally call for caissons down to bed rock.

Very little real engineering skill is required to sink wells for caissons in Chicago. Hard conscientious labor is all that is required. There are one or two precautions that the engineer should insist upon however. The well should be amply braced to prevent bulging and there should be no space between the excavation and the lagging. If this is attended to there will be no movement of clay, hence no settle-

ment of other structures and the only objection to the caisson will be removed

It seems impossible that a more satisfactory form of foundation could be devised for simplicity and efficiency and from the indications it seems that the vexing problem of foundation building in Chicago is solved for the tall buildings at least.

No fewer than twelve large buildings were erected in 1905 in the business district of Chicago, all on caisson foundations. The prospect for 1906 is even greater as contracts have been let for many other buildings with the same kind of foundations. Chicago which has been the leader in this class of work may still develope another idea for foundations but if any other idea is more satisfactory than the concrete caisson to bed rock

that foundation will have to possess ideal qualities.

CAISSONS AND RETAINING WALLS.

(See also, General Work, pp. 1-7.)

ENERAL CHEME.

The basement will be cleared of machinery by the owner and general contractor, respectively, and then the contractor for caissons and retaining walls shall shore up the building wherever the present columns, walls or fastenings, &c., interfere with the sinking of caissons and walls. This shoring to be done by an approved regular house raiser of high standing and experience. The shores to be shifted as required to properly and expeditiously carry forward the work. He shall then sink the caissons to the proper depth, and trench for and fill and complete the retaining walls. The mason shall underpin the party and south walls.

All work of excavation and construction of caissons and retaining walls shall be done with three (3) shifts of men twenty-four hours of every day continuously, Sundays and holidays included.

All work west of the center of alley (except the alley arches and paving, shall be included in this contract under a separate specification.

HORING.

The contractor shall do the shoring of the party wall required for sinking the caissons and retaining walls, as well as any shoring of the remainder of the building required to support the structure during the prosecution of the work.

IZE AND EPTH OF AISSONS.

All caissons (except under Columns 33 to 52, both inclusive, shall stop on hardpan, which is approximately 85 to 87 feet below inside grade.

After hardpan is reached and approved by the superintendent, the contractor shall form a bell twice the diameter of the caisson and the sides sloping to meet the caisson walls at the diameter of the caisson above the bottom; that is, for a caisson six (6) feet in diameter, the bottom of the bell shall be twelve (12) feet in diameter, and the belling shall begin six (6) feet above the bottom.

Caissons under columns 33 to 52, both inclusive, shall go to rock, and in filling the staving shall be removed just ahead of the concrete in these twenty (20) caissons.

When the rock is reached, it shall be drilled at least eight (8) feet with a point or rose drill, and the bottom shall be approved by the architects before filling the caissons.

Bed rock is approximately 105 feet below inside grade. Any variation from this amount shall be assumed by the contractor.

SINKING CAISSONS.

The contractor shall sink the caissons, keeping the diameter uniform and the casing plumb and true throughout its depth.

A cofferdam shall be constructed around the head of each caisson, made of a water-tight boxing sunk into the blue clay, and thoroughly puddled with clay around the outside to prevent all surface water from penetrating to the wells.

The caissons along the north wall shall be sunk alternately, and the work shall be carried on in such a manner as to disturb the adjoining premises as

little as possible.

Excavated material shall be removed from the premises as fast as excavated; the contractor for the caissons erecting a suitable hoist in the structure erected by General Contractor for that purpose.

A center stake plumbed from the top of the well shall be used continuously for carrying down the work, and every precaution shall be taken to make the excavation the net diameter of the outside of the lagging, and thus avoid all open space between the back of the lagging and the face of the excavation.

Steam or hand power may be used for lifting the excavated material out of the wells and the contractor shall install such tramways, hoists, chutes, storage bins, platforms and ramps, &c., as may be required for the proper handling of the excavated material, concrete, staving, &c., entering into the construction.

STAVING AND RINGS.

Three-inch matched staving in 5-ft. lengths shall be used, held in place with heqvy wrought iron sectional rings, put in place in sufficient numbers to prevent all bulging or movement of the lagging. The staving shall be left in place, except in caissons under Columns 32 to 52, both inclusive, which shall be removed as before specified; the rings being so set that when the bottom ring is removed the concrete shall retain the bottom of the lagging. Top ring of each set of lagging shall be left in until concrete has nearly reached its level.

UMPING. Should any water or other material penetrate to the wells, necessitating pumping, the contractor shall furnish the pumps and attendance required for removing such material.

ONCRETE. The concrete filling shall be composed of one part properly seasoned Portland cement, three (3) parts clean, sharp, fine washed Torpedo sand and five (5) parts of broken stone, of random size, ranging from 1/2 to 1-1/2 inches.

Stone to be free from dust or other foreign substance (being washed if necessary to reach this condition.)

Cement to be any approved brand of Portland cement whose test for fineness is above ninety-five (95) per cent for 100 screen, and whose tensile strength in one to three sand mixture is above one hundred seventy-five (175) pounds per square inch for seven days' set, one in air and six in water.

All cement to be tested by an engineer approved by the architects.

Concrete to be mixed in a Smith concrete mixer of ample capacity to insure the rapid prosecution of the work.

Concrete shall be lowered into the caissons through a telescoping sheet steel chute, and two men shall be kept in each caisson continuously during this filling to spread and tamp the concrete and remove the rings.

Concrete shall be thoroughly tamped in 6-inch layers.

The bottom section of the chute to be made to swivel, with handles for swinging, so that the concrete can be evenly spread.

Size of chute to be proportioned so that the lapsed interval of time occupied by the dropping of the concrete from the top to the bottom of the chute shall not dangerously approach the limit of initial set of the concrete.

The upper fifteen inches of each caisson shall be composed of one part of the cement above specified and two (2) parts fine granite chips, and in the top shall be imbedded the grillage furnished by the iron contractor.

SPECIAL BRACING AND SHORING.

In sinking the trenches for the retaining walls on the four (4) sides of building, they shall be so excavated that the inside face of the outer staving shall become the outer face of the concrete wall. As the excavation is carried forward staving, same as specified for caissons, shall be set in the trench as to constitute the "forms" for the wall and these forms shall be held apart by stringers with house raiser's jacks, so arranged that they can be screwed up continuously and so set that the beams and channels can be set in the trenches before concreting. The shoring to be done by an experienced house raiser approved by the architects. The holding of these walls against movement continuously from start to finish and the shoring up of the walls until the setting of iron work and concreting of floor arches and setting of concrete struts is imperative to avoid settlements and movements to adjoining property and streets.

The bottom section of the chute to be made to swivel, with handles for swinging, so that the concrete can be evenly spread.

Size of chute to be proportioned so that the lapsed interval of time necessary for the dropping of the concrete from the top to the bottom of the chute shall not dangerously approach the limit of initial set of the concrete.

The upper fifteen inches of each caisson shall be composed of one part of cement above specified and two (2) parts granite chips, and in the top shall be imbedded the grillage furnished by the iron contractor.

SPECIAL BRACING AND SHORING.

In sinking the trenches for the retaining walls on the four (4) sides of building, they shall be so excavated that the inside face of the outer staving shall become the outer face of the concrete wall. As the excavation is carried for each staving, same as specified for caissons, shall be set in the trench as to constitute the "forms" for the wall and these forms shall be held apart by stringers with loose raker's [illegible], so arranged that they can be removed [illegible] continuously so as to get past the bottoms and [illegible] to the trenches before concreting.

The shoring to be done by an experienced house mover approved by the Architects. The holding of these walls against movement continuously from start to finish and the shoring up of the walls until the setting of iron work and centering of floor arches and setting of concrete arches is imperative to avoid settlements and movements to adjoining property.

If the limited amount of space or the excessive pressure demands special jacks for this work they shall be promptly furnished by the contractor.

The shoring of the elevated railroad column, of the retaining and building walls during the construction of these walls shall be done as before specified.

RETAINING WALLS.

The curb wall being accessible shall be constructed as follows:

The contractor shall remove the paving and excavate the the necessary depth to start the sheet piling before the curb wall is removed.

He shall then drive six (6) inch Wakefield sheet piling 22-ft. long, approximately 2-ft. outside of the finished face of the curb wall along the street front.

Heavily braced strong timbers to be used as a guide to secure perfect alignment and fit.

The driving to be done with an approved steam hammer and work to be done so as not to disturb tenants of adjoining buildings; or if preferred by architects, staving shall be set and braced as hereinafter specified. Below the sheet piling of the curb wall, staving shall be set as before specified for retaining walls, and the trenches excavated and shored same as specified for retaining walls. All staving used for faces of concrete to be of dressed lumber. As the trenches for curb and retaining walls are bottomed out, the steel framing shall be set by the Structural Iron contractor under the direction of the caisson contractor, and then the trenches shall be filled in around beams with concrete as before specified (as to quality, ingredients and method of mixing) for caissons and thoroughly tamped in and

around beams continuously to top of wall, not allowing one layer to set before the next is applied. Concrete for these curb walls shall be as specified for the caissons. (See caisson specification, p.14.)

TILE DRAINAGE. The contractor shall lay a 4-inch vitrified open rejoint drain tile around the outside of curb and retaining walls, laid on 8-inch boards, filled in around the pipe with broken stone. Shaving to be left open twelve (12) inches in height, in order to allow the drain to be put in.

Make connection through walls at 40-ft. intervals with 4-inch tarred and threaded pipe.

The contractor shall ascertain the number, size and location of sub-drainage, gas, water, telephone, electric light connections, &c., which will have to be carried through this wall; and he shall notify the plumber in ample season, and see that sewer, subdrainage, gas and water pipes, &c., are in place before the wall is built; and for such connections as cannot be gotten in place before the wall is built, the Mason shall furnish cast iron thimbles.

No cutting of this wall will be permitted after it is completed.

SHORING OF ELEVATED STAIRS. The contractor shall shore and protect the elevated stairs and keep a constant access to them.

SHORING AFTER COMPLETION. After walls are completed and before any excavation of general lot is begun, the contractor shall shore the top of all walls. All shoring to be done by an experienced houseraiser approved by the architects, and competent and experienced men shall be kept on the premises at all times to keep the screws tightened up everywhere.

As the excavation proceeds, additional beams, drums and braces shall be set to take all pressure against all walls and hold them against the slightest movement, until all steel below grade is set and crete struts and floors in place. The caissons under south wall to be specially shored and held.

REMOVAL OF RUBBISH.

The contractor shall do all excavating for caissons and retaining walls, bringing the clay, &c., to the platforms at or near the basement level, and from this point the mason contractor shall remove all his shoring, beams, scaffolding, &c.